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Performance Correlates of

Social Behavior and Organization in Non-Human Primates

Annual Report

September 1979

(1 August 1978 - 30 September 1979)

Bradford N. Bunnell

Joseph D. Allen

Supported by

U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Frederick, Maryland 21701

Contract No. DADA 17-73-C-3007

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The purpose of this research is to identify and investigate performance variables that are correlated with social rank, social behavior, and social organization in monkeys of the genus Macaca. Twenty-three male Macaca fascicularis (Java, or crab-eating macaques) from three troops of animals were tested on a number of operant, problem solving, and open field tasks. Performance on several of these tasks was related to social behavior and social

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Table of Contents

Summary, Abstract, or Digest

The purpose of this research is to identify and investigate performance variables that are correlated with social rank, social behavior, and social organization in monkeys of the genus *Macaca*. Twenty-three male *Macaca fascicularis* (Java, or crab-eating macaques) from three troops of animals were tested on a number of operant, problems solving, and open field tasks. Performance on several of these tasks was related to social behavior and social status. Experimental manipulations of the social organization and behavior of the animals produced concurrent changes in performance on two of the tasks. The results, for the most part, confirmed and extended findings from previous work on this project. In addition, the year's work included additions and improvements to the methods for recording and analyzing social behavior. Finally, equipment and procedures for doing operant testing in the social group situation were developed and tested.

Foreword

In conducting the research described in this report, the investigators adhered to the "Guide for Laboratory Facilities and Care" as promulgated by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences - National Research Council.

Body of the Report

A. Social Behavior and Organization:

(1) Group composition as of 8/1/79.

There are now three troops of animals under observation:

# of animals in each age/sex category*

	Adult		Subadult		Juvenile		Infant	
TROOP	M	F	M	F	M	F	M	F
"T"	7	13	1	0	1	4	3	5
"NT"	8	10	4	0	3	3	3	5
"I"	9	0	0	0	0	0	0	0

*Males over 6 years old and females over 4 years old are classified as adults. Males 4-6 and females 4 years old are subadults. Juveniles are over one year old (both sexes).

The age/sex ratios for T- and NT-Troops are within the general ranges found for naturally occurring groups of *M. fascicularis* (Angst, 1975).

(2) Social testing.

Each group of animals is housed in an outdoor compound 12.2 x 3.4 x 2.0 meters high. The compounds are connected to indoor quarters that are heated and air conditioned. Each indoor cage is 6.1 x 1.2 x 7.5 meters high; the runways connecting the compounds with the indoor cages are 1.3 meters wide and 1.3 meters high. Metal perches and water fonts are located in both the indoor and outdoor sections. Sections of metal fencing, placed lengthwise in the outdoor compounds, serve to provide partial separation of the animals and, in effect, to increase the living space of each group. An observation station, 1.5 x 1.6 meters in area and containing electrical power and plug in jacks for the keyboard system used in recording social data, is centrally located in each outdoor compound. Swinging doors provide passage between the indoor quarters and the runways and guillotine doors are located between the runways and the compounds.

Observations of social behavior (usually one hour per group five times a week, weather permitting) are scheduled in accordance with the laboratory tests being conducted with the animals. In recording social behavior, the observers use a keyboard-tape punch system, entering the code for the animal exhibiting a behavior, the code for the behavior itself, and then the code for the animal toward which the behavior is directed for each event which occurs. The system automatically punches the time of occurrence of the behavior and a code symbol which identifies the keyboard on which the behavior was recorded. As many as four keyboards may be used with the system. Frequency, latency, durational information and response sequences may be obtained from the data tapes. Additional analyses provide response matrices for each animal with respect to every other animal in the group. The behaviors that are currently being scored with the Java monkey groups are given in Table 1.

Social rank is defined by defeats. The occurrence in any animal of a submissive behavior indicates that that animal is inferior in rank to the animal toward which the submissive signal is directed. The means by which one animal established and maintains dominance over another (e.g., by attack, threat, teaming up with another animal) may vary from animal to animal, from group to group, and from situation to situation. By recording and analyzing the social behavior of our animals, we define both the behavioral constancies and the range of variation seen in each of our subjects. This gives us a more sophisticated measure of social status and social organization than a simple assignment of rank. With such measures, the probability of detecting additional correlations between social behavior and performance on laboratory tasks is enhanced and the attempts to perform the essential causal analyses of these relationships greatly facilitated.

In the analyses of social behavior we are now using, each day's tape is initially analyzed by a PDP-8 computer which gives:

(a) A listing of the number of behaviors recorded for each animal for that observation period and a listing of the total frequency of occurrence of each behavior.
(b) A listing of the frequency with which each animal exhibited each behavior during the observation period.
(c) A listing of the frequency with which each behavior exhibited by a given animal was directed toward each of the other animals in the troop.

These listings are then used to monitor day-to-day interactions in each group and to pinpoint changes in the relationships between individuals. A typical strategy is then to summarize the group relationships occurring before and after a major change in group structure by combining several days' data in a matrix analysis. In this procedure, the computer goes through all of the data and determines the social rank of each animal on the basis of who is defeated by whom, using the submissive behaviors given in Table 1. It then prints a series of six matrices, using the same rank order, or dominance hierarchy, it determined from the analysis of the submission scores. In each matrix, the frequency of occurrence of each behavior or class of behaviors selected for inclusion in that matrix is given for each animal with respect to every other animal in its group. (At present we are limited to 24 x 24 matrices; usually the behavior of the 24 oldest animals in a group is scored. In some cases, one of the 24 entries is used to include the behavior of all the rest of the animals not listed individually.) Four of the matrices are used to summarize the combinations of behaviors listed under the functional categories Aggressive, Submissive, Sexual, and Other Social that are given in Table 1. For the other two matrices, any individual behavior of interest may be selected. Thus, we might look at contact aggression as compared to overall aggression, or obtain separate matrices for play, groom, etc.

Examples of the matrices derived from the social data were presented in our last annual report on this project (Bunnell and Allen, 1978). Other computer programs have also been developed which summarize ranks, behavior frequencies and which distinguish between intermale behavior and behavior of the entire group.

The recent literature has provided a good background on social behavior and organization in *M. fascicularis* in both wild and captive groups (Angst, 1975, deWaal, et al., 1976) against which we can assess our own data.

In our early work with the social behavior of these animals, we concentrated on the behaviors of the males that were being tested on the laboratory tasks. Observers of social behavior scanned the groups and tried to record all of the interactions that were taking place among all of the animals in each troop. Because of the orientation of the studies toward the males that were being given laboratory tests, however, it gradually became clear that the observations were being biased in favor of these animals, at least in terms of the likelihood that their behavior was more likely to be recorded than that of animals that were not undergoing laboratory testing. The advantage of

TABLE 1

Java Monkey Behavior Categories

Agonistic Behaviors:		
	Aggressive	
		Chase
		Threat (open-mouth)
		Charge
		Slaps
		Bites
	Submissive	
		Avoid
		Grimace
		Squeal
		Flee
	Other Agonistic *	
		Lid
		Lip Smack
		Enlist
Sexual Behaviors:		
		Sexual Present
		Mount (no thrusting)
		Mount (with thrusting)
		Masturbate
		Genital Manipulation (other animal)
		Genital Sniff
Other Social Behaviors		
		Present to Groom
		Groom
		Ventral-Ventral Hug
		Ventral-Dorsal Hug
		Sit Next To (physical contact with other animal)
		Play *
Non-Social Behaviors		
		Self Groom
		Move
		Sit - No Social

* "Lid", a flash of the white eyelids, "Lip Smack", and "Enlist" are scored, but are not currently used in the analyses described in the text. Lid is a part of the "pout threat" (Angst, 1975) commonly used by subordinate animals, lip smack is ambiguous and perhaps should not even be classed as agonistic, while enlisting occurs very infrequently in our groups. "Play" occurs only in infant and juvenile animals and is difficult to define reliably.

this was that the nature of the relationships between these males and the other group members was defined with considerable accuracy and reliability. The disadvantage was that relationships between non-laboratory tested animals were less accurately recorded. Because we now feel that these other relationships have considerable importance in the total dynamics of the group and in the ways such dynamics contribute to the performance of these males on the laboratory tasks, we have begun to emphasize two additional approaches to the recording and analysis of social behavior during the last 12-15 months.

First, we have begun to use a focal animal observation technique to supplement and, in some somes, to replace the group scan observation procedure. In the focal animal procedure, a given animal's behavior is recorded for a stated time interval after which another animal becomes the focus for the observations for a second interval, and so on. By selecting the focal animals on the basis of what has emerged from the group scan observations or in order to test hypotheses about what might be expected from a particular animal following an experimental manipulation, more data, and more reliable data, can often be obtained for a given period of time. Use of equal time intervals for focal observations also makes direct comparisons of frequency, latency, and durational events more feasible.

Second, by adopting the cluster analysis technique developed by one of the former assistants on the project (Fischer, 1977), we have found a way of assigning a probability value to various constellations of group interactions. Early results from the application of Fischer's technique (Bunnell and Allen, 1978) have been largely confirmed by data obtained from T- and NT-Troops in August, 1979 using focal animal procedures. Adult females receive a considerable amount on nonagonistic social attention from their daughters, but reciprocate such attention only moderately, prefering to expend their attention on their adult and subadult sons. The adult sons direct most of their non-agonistic social behavior toward adult females when they (the sons) are high ranking or toward other adult males if they are low ranking. Subadult and juvenile males interact in nonagonistic social behaviors with their peers and low ranking adult males. An "incest taboo" appears to be quite strong with respect to son-to-mother sexual behavior. (A brother-sister taboo may also operate, particularly if the mother is present in the troop, but these data need to be confirmed.)

A third approach will be implemented during the coming year. In their studies of captive _M. fascicularis_, deWaal and his coworkers (deWaal, et al., 1976) have demonstrated the potential importance of the participation of more than two animals in a single social interaction. After careful examination of the data which we have obtained from concentrating primarily on diadic interactions we have come to the conclusion that it is essential that we add multianimal interaction scores to our observations. An understanding of the use of both enlisting behaviors and of the displacement of agonistic responses is going to be crucial to the development of a behavioral model of social pressure and stress which is a critical element of the research that is to be proposed for the coming year. The procedure for obtaining these data will be based on that used by deWaal.

Another reason for obtaining and analyzing multianimal interactions is to use them in deciding upon the protocols to be used in performing experimental manipulations of the social situations. Until this past year, our primary method of manipulating the social situation has been to remove and then replace one or more of the males being laboratory tested. Also, during the first year, we were able to introduce unfamiliar animals into the groups from among the pilot animals that were used in the early laboratory tests. This past year we also formed a new troop by combining males from T- and NT-Troops and performed still another manipulation by switching a high ranking male from each foundation troop to the other troop. These manipulations are useful and will continue to be employed in the future. The new approach that we have begun to use is to try to manipulate the social environment of a given animal by manipulating his mother, sisters, peers and/or allies, etc. We have now done this a few times with mixed results. We expect to get more striking and more consistent results when we have a definition of multianimal interactions. We expect that the removal and replacement of two or more animals based upon such observations will be necessary to produce and/or relieve the kinds of social pressures we think are the keys to the performance changes we have observed.

Finally, we plan to continue the search for social "profiles" for each animal undergoing laboratory testing. Attempts to cluster such profiles to see if the animals can be classified into categories which relate to dimensions of performance have not yet been successful. Increased use of focal animal recording procedures during the coming year is expected to give us a more accurate score for each behavior for each animal and provide a better test of the soundness of this idea.

B. Complex Problem Solving:

The initial work which we did with rhesus monkeys showed that high ranking animals tended to respond at a slower rate than low ranking animals when they were all tested on a fixed interval operant conditioning schedule (Bunnell, Kenshalo, Allen, Manning and Sodetz, 1979a and Bunnell, Kenshalo, Czerny and Allen, 1976b). Because the lower rate of response was more efficient in obtaining reward, it was suggested that the relationship between social variables and performance on a complex learning task should be studied in order to determine whether or not high status animals had a general tendency to deal with learning tasks more efficiently than low ranked animals.

Males from both T- and NT-Troops were tested on a brightness discrimination reversal learning task using the Wisconsin General Test Apparatus (WGTA). After initial learning the correct stimulus was reversed and the animals trained to a criterion of 36 correct responses on a series of 40 trials. The five oldest males from NT-Troop and nine males from T-Troop completed at least 10 such reversal problems. Comparison of the performance of the animals holding the top three ranks in each troop with that of the remaining animals showed that the high ranking animals made more errors

in all stages of testing (Figure 1). Only three animals, all of them low ranking, had given evidence of "error-free" reversal, i.e., had developed a reversal learning set, by the end of 10 reversals (Bunnell, Gore and Perkins, 1980a).

A second study has examined complex learning in more depth (Bunnell and Perkins, 1980b). Using a procedure suggested by Meyer (1971), animals were first trained on 6-trial object quality learning set problems. This was followed by training on 10-trial learning set problems. Reversals were introduced into the next stage of training by reversing the correct stimulus in a pair at a point partway through each problem. (This point was varied to keep the animals from anticipating the reversal; following the reversal trial, three more trials with the reversed stimulus as correct were always given.) Finally, the reversal sets were extinguished by reversing the correct stimulus for only one trial of each problem and then making the originally correct stimulus correct for the remaining three trials on that problem. The same nine animals from T-Troop that were tested on brightness discrimination reversal were tested on this task. They were all given 360 6-trial object quality learning set problems at the beginning of the study. Training on the 10-trial problems was continued until they reached 85% accuracy on trial-2 performance for 20 consecutive problems. The same criterion was used for the trial following the reversal and reversal extinction stages of training. Eight animals from NT-Troop, including the five which had completed at least 10 reversals on the brightness reversal problem were tested on the object quality set problems. They differed from the T-Troop males in that they were run to an 85% correct trial-2 criterion on the six-trial problems instead of being given 360 problems.

The high ranking animals from both troops made more overall errors in reaching criterion on the 6-trial problems than low ranking animals. However, trial-2 performance on this stage of training did not differ for the two groups. On 10-trial problems, the T-Troop males that had been overtrained on the 360 6-trial problems transferred their performance to the 10-trial situation with very few errors. NT-Troop males, without overtraining, did much worse in general and the high ranking NT males made significantly more trial-2 errors than the low ranking NT-Troop males. High ranking animals from both troops made significantly more errors than low ranking animals on the critical trials following the reversal trials in both the reversal and the reversal extinction stages of training. However, the object quality sets (trial-2 performances) of all of the animals carried over to the reversal and reversal extinction stages at near criterion levels (Table 2).

In Meyer's (1971) terminology, intraproblem performance gives a measure of the learning of discrimination habits. The poorer performance of the high ranking animals on both the brightness discrimination reversal problems and on acquisition of the object quality discriminations <u>within</u> problems represent performance differences in habit learning. Trial-2 and critical trial performance <u>across</u> problems are said to represent the learning of concepts (e.g., the win stay - lose shift strategy, perhaps) or learning sets. Thus, high ranking animals may be said to be impaired on the

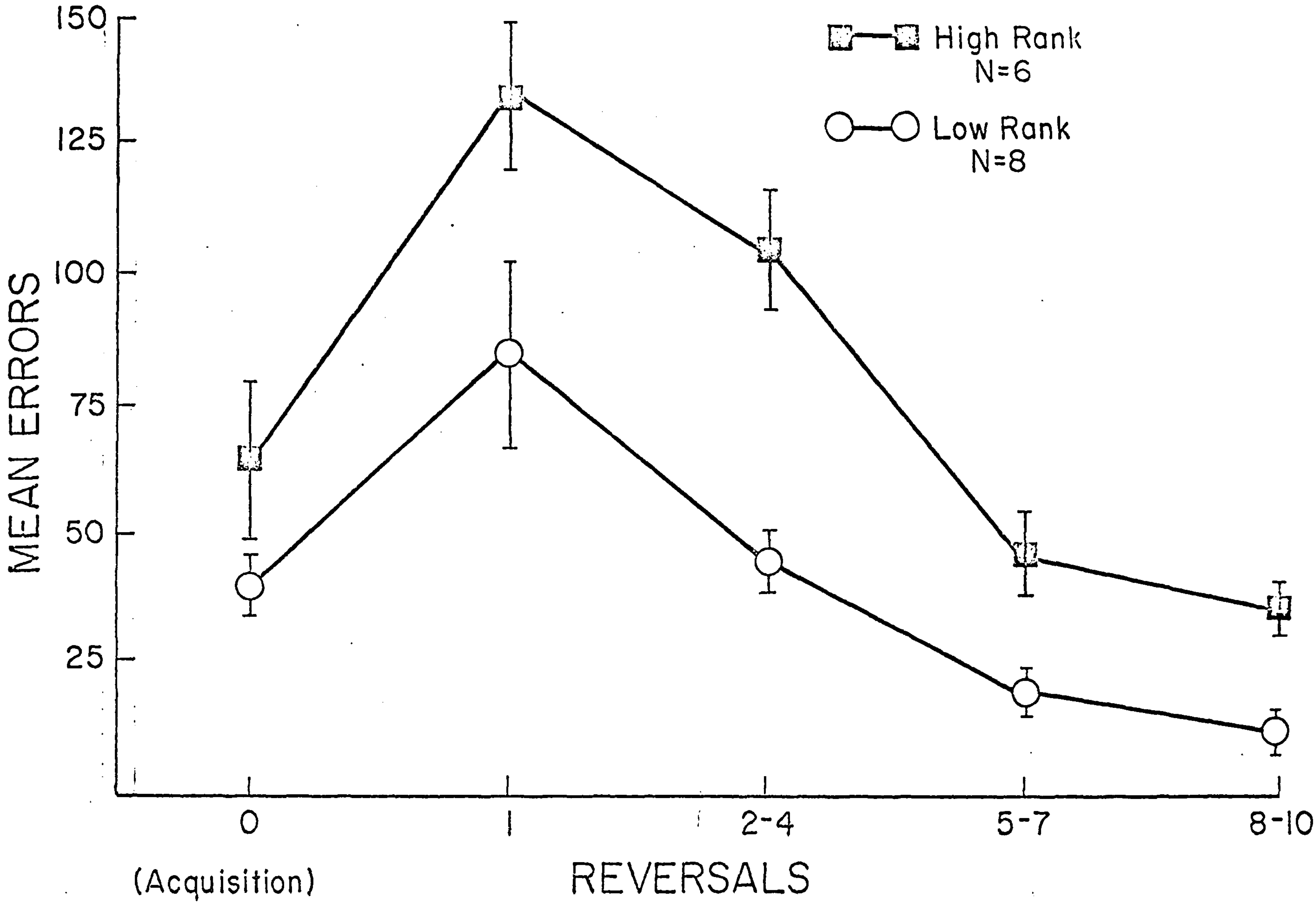

Figure 1. Mean errors to criterion on a brightness discrimination reversal task by high and low ranking *M. fascicularis* (Bunnell, Gore and Perkins, 1980a).

TABLE 2

Mean Trial-2 and Critical Trial Errors to Criterion by High and Low Ranking *M. fascicularis* for Four Stages of Training*

	6-trial Problems	10-trial Problems	Reversal Acquisition	Reversal Extinction
High Rank	$\bar{X} = 47.20$	$\bar{X} = 26.33$	$\bar{X} = 50.43$	$\bar{X} = 96.25$
	N = 5	N = 6	N = 7	N = 4
Low Rank	$\bar{X} = 38.75$	$\bar{X} - 7.00$	$\bar{X} = 17.44$	$\bar{X} = 48.64$
	N = 12	N = 11	N = 9	N = 11

* One animal did not complete reversal learning and two did not complete reversal extinction.

acquisition of discrimination habits, reversal sets, and reversal set extinction. They did not differ from lower ranking animals in the formation of object quality learning sets, however. The fact that overtraining on the 6-trial problem allowed all of the T-Troop animals to transfer their performance to the 10-trial problems while the high ranking NT-Troop males did worse than the low ranking animals from NT, suggests to us that it is a change in test conditions and contingencies that produces the high vs low rank performance differences, not the type of problem presented. Apparently overtraining can protect the animals' performance from the effects of such changes, however.

The most interesting result from the object quality learning set study was that the animals included in the high rank group were not all the same as those that made up the high rank group in the brightness discrimination study. In other words, it has been possible to show that changes in relative performance on the two tasks are related to changes in individual animal's social status that occurred in the time between the two experiments. (A similar effect also was found between stages of the second experiment for animals that exhibited status changes over the 6 to 13 months required to complete testing.)

Analyses of the response patterns on the reversal and reversal extinction stages exhibited by the animals did not reveal any particular strategies or hypotheses that distinguished the high and low ranking groups. Both stopped responding to the formerly correct stimulus with equal ease - it simply took the high ranking animals longer to start responding to the newly correct stimulus consistently.

During the current year, we have been retesting the animals by running them through another cycle of reversal learning and extinction on the object quality learning set problems. We had hoped to run them through at least two such cycles in conjunction with experimental manipulations of the social structure of the groups. However, it has taken over a year to get through one cycle and it is clear that it is not practical to use this technique to study short term relationships between status and performance. What the year's work has done, however, is to verify the relationship between rank and performance - as rank has changed so has performance, and in the expected direction. The WGTA situation seems to be a very powerful tool for disclosing performance differences that relate to social status.

During the coming year we will see if we can establish a relationship between plasma cortisol and WGTA performance. We will test six animals from each group on reversal/reversal extinction while monitoring both cortisol levels and social behavior and status.

There is apparently something about the establishment and maintenance of high social status which interferes with performance on complex problem solving tasks. We think that this may well be a response to the stresses and pressures of the social situation which produces progressively more primitive approaches to the solution of difficult or altered problems - an idea taken from Harlow's (1959) concept of regression. If the data from

forthcoming experiments provide support for this idea, it should then be possible to teach the animals strategies which will protect their performance from such interference.

C. Open Field Tests:

A variety of tests have and are beirg conducted in an open field arena to determine whether or not there are relationships between social variables and measures frequently associated with emotionality, responses to unfamiliar environments, locomotor activity, reactions to novel stimuli, and the like.

Testing is conducted in a square open field, 3.66 M on a side and 1.83 M high which has been constructed in a large room indoors in the laboratory building. The walls, constructed of asbestos cement board, and the concrete floor are painted white. The floor is divided into 16 equal squares by a painted grid; five threaded studs, one in the center and the other four arranged in a square pattern equidistant from the center stud and the arena walls, are embedded in the floor. These are used to attach novel objects used in some of the studies. The arena is covered with 2 in. chain link fencing and is illuminated by four 150 watt floodlights placed above the chain link ceiling. There are two guillotine doors located at diagonally opposite corners of the arena; these doors exactly fit the dimensions of the doors of our animal transport cages. A larger door is located along one wall and allows people to enter the field to place objects in the field and for cleanup. An elevated platform is located along the outside of one wall which enables the observers to look down into the arena. An opaque curtain on either side of a large one way mirror prevents the animals from seeing the observers. Also located at the observer's station are the ropes controlling the guillotine doors and a keyboard which is connected to the laboratory computer located across the hall. Punching the appropriate keys on the keyboard for the different behaviors exhibited by the animals causes the data to be stored in the computer; at the end of a test, the data can be punched out on paper tape and/or stored on floppy disc for later analysis.

Tests are run for either three or five consecutive days on the problems we have devised for use within the open field; the number of days depends upon the nature of the problem, the configuration of the open field, and the amount of time necessary for performance to stabilize. The basic procedure is to bring each animal to the apparatus in a transport cage, open the guillotine door, and allow the animal a maximum of 15 minutes to emerge into the open field. "Emergence" requires the animal to enter the arena and move beyond the first square of the field (a distance of @ .92 meters). When the animal has emerged, the guillotine door is closed behind him and the behavior of the animal during the ensuing five minutes is recorded. At the end of five minutes, the guillotine door is reopened and the animal's latency in returning to the transport cage is recorded as are the behaviors that occur during this latency period. In the test situation with an empty arena, then, the behaviors that are recorded are:

(1) Head Out Latency: Time from opening the guillotine door until the animal pokes his head through the door of the transport cage into the arena. (max. 900 sec.)
(2) Body Out Latency: Time from opening of guillotine door until the animal enters the square of the arena directly in front of the guillotine door. (max. 900 sec.)
(3) Number of Returns: Number of times animal reenters transport cage after entering first square ("body out").
(4) Emergence Latency: Time from opening of guillotine door until animal "emerges" (as defined above).
(5) Exploratory Moves: Number of squares traversed during the five minutes following emergence until the guillotine door is reopened.
(6) Return Latency: Time from the reopening of the guillotine door until the animal reenters the transport cage.
(7) Return Moves: Number of squares traversed during the return latency period.

The time spent on the floor is differentiated from that spent hanging from and moving about on the ceiling.

With novel objects present, the frequencies of the following additional behaviors are also recorded:

(8) Lip Smack
(9) Orientations to object(s)
(10) Manipulations of object(s)
(11) Threats to object(s)
(12) Bites (object)
(13) Other contacts with object(s)
(14) Vocalizations
(15) Self Directed Behaviors (groom, masturbate, etc.)

Two replications of a test in the bare open field were conducted one year apart. In general, there was a significant positive correlation between high social rank and short emergence latency and between high social rank and number of squares traversed in both T- and NT-Troops (see Bunnell and Allen, 1978 for more details).

In February, 1978, one month after completion of the second test in the bare field, the animals were tested again. This time a stuffed teddy bear @ .33 M long by .25 M high was placed in the center of the field. The stuffed toy was mounted on a wheeled platform that was pivoted on the stud in the center of the floor so that the toy would spin when touched with any force. There was a reliable increase in emergence latency for the T-Troop males; however, Capone, Madison, and Oliver refused to enter the field. In the six animals that did enter the field, there was a near perfect correlation between high rank and high locomotor exploration. In NT-Troop, emergence latencies tended to be longer in the five oldest and highest ranking animals - the exception here was Eju who emerged on all three trials with the novel object in the field after failing to do so in the bare field. Eju, ranked third, did relatively little exploring (although he attacked and bit the stuffed toy more than any other animal)

and the two top ranked animals, Knees and Ian did the most exploring, following by Alabama, ranked 4th, and Barker, ranked fifth (rho = +.82, p = .09, two tailed).

There were no consistent relationships between social rank and behavior toward the novel object. In T-Troop, contacts between the animals and the object were relatively few and those that were made bore no particular relationship to social status; the lower ranking animals tended to show more orienting behavior. In NT-Troop, the higher ranking animals tended to contact the object more than the other animals, but the relationship was not very strong.

In February and March of 1979, all animals were tested again, this time with four objects placed in the field. After three consecutive days of exposure to these objects (the objects were not placed in the same location two days in a row), a new object was introduced on day 4. This was always placed in the location closest to the guillotine door in full view of the animal when the trial began. The results were disappointing. There was one animal from each of the three troops that refused to enter the field on all four days; four other failed to emerge on at least one day. There was no relationship between rank and failure to emerge, nor was there any correlation between rank and either emergence latency or amount of exploration in those animals that did emerge. The behavior of many of the animals was quite variable from day to day and it is possible that they should have been given more exposure to the situation. At present we are repeating the study using the nine I-Troop males before deciding whether to continue with the novel object tests or turn to another situation.

Next year we will do two kinds of social tests using the open field. The first type of test will involve releasing the subject animals in the open field which will contain either a familiar or an unfamiliar animal. The second situation will compare an individual's response to a novel object in the open field when he is tested alone to his behavior when he is tested with a companion. Companions will be selected on the basis of the strengths of relationships as revealed by the analyses of the social behavior data.

D. Operant Conditioning:

Meier and his coworkers (e.g., Bartlett and Meier, 1971) have looked at operant behavior in a communal group of rhesus macques. Using Fixed-Ratio (FR) schedules for monkey chow (FR-32 for 22 hours a day) and fresh fruit (FR-16 for 2 hours a day) as incentives, they found that rate of bar pressing was significantly correlated with dominance status. The higher ranking animals responded at a slower rate. Individual differences in rate or intensity of response did not vary as a function of social context, suggesting that the differences might be quite stable, perhaps as a function of a history of differential learning of dominance related behaviors. (Dominant animals had priority at the manipulandum; they pressed at low rates, and paused to eat the food after it had been delivered. Subordinate animals would not respond in the presence of higher ranking animals; they pressed at high rates and would often resume pressing while eating a recently delivered piece of fruit.)

The first reliable relationship between social variables and performance that we found was the result of studies using rhesus monkeys that were tested on a Fixed Interval - 1 minute schedule (FI-1 min.). When reinforcements were omitted, randomly, after 20% of the intervals, the ratio of nonreinforced to reinforced responses (omission ratio, or OR) was higher in high ranking animals than in low ranking animals. Baseline responding on the FI 1-min schedule was lower in the high ranking animals (Bunnell, et al., 1979a and 1979b). In interpreting these data, we suggested that the lower baseline responses rates by high ranking animals might be a carryover of the more deliberate performance operant performance observed by Bartlett and Meier in the group situation. The differences in ORs between high and low ranking animals was discussed in terms of Strayer's (1976) hypothesis that status related differences in response dispositions reflect individual adaptations to group living. The higher omission ratios of the higher ranking animals were thought to reflect increased response inhibition on the part of the lower ranking animals. Lower ranking animals are continuously exposed to aversive social control which requires the inhibition of certain responses that would be inappropriate in the presence of higher ranking animals; higher ranking animals would not be required to inhibit such responses as frequently.

The ratios of nonreinforced to reinforced responses (ORs) on the FI 1-min schedule have been said by some (e.g., Amsel, 1958) to be a measure of frustration following nonreward. Others, (see Staddon, 1970, 1972) believe that the response bursting which typically follows nonreinforcement under this paradigm is not due to an increase in excitation following nonreward but is explained by an inhibitory effect of reinforcement so that nonreinforcement leads to enhanced responding.

The relationship between high ORs and high social rank that we found in rhesus monkeys has not been as apparent in Java monkeys tested on the FI schedule. Although the expected trend was there (more so in T-Troop than in NT-Troop animals, incidentally) the correlations between rank, frequency of aggressive behavior, or frequency of submissive behavior on the one hand and ORs on the other were nonsignificant. When, however, we looked at the correlations between rates of responding after reinforced intervals with rates after nonreinforced intervals, we found that the expected correlations between ORs and rank did appear in animals whose reinforced/nonreinforced response rate correlations were high and positive, but not when the correlation was insignificant, or large negative. This suggests that the animals may have at least three ways of dealing with the schedule contingencies, or that perhaps multiple factors contribute to the OR (activation? reinforcement inhibition effects? + something more?).

One attempt to understand what may be going on has been to use a paradigm in which we have tried to get all animals onto a high, stable rate of baseline responding before omitting reinforcement and have invented a manipulandum which seems to have, at least for us, a higher face validity in the production of "frustration" in our subjects. The manipulandum consists of a hopper with a transparent plexiglass door that is latched until the schedule requirements have been met. A banana pellet is always visible behind the door, and the animals' presses against the door are scored. When the animals have stabilized their performance on the VI 1-min schedule, a condition is introduced whereby reinforcement is omitted on certain trials. This is done by dropping the pellet through the bottom of the hopper just as the schedule requirements have been met.

Testing on this task was completed for 9 animals from T-Troop and 12 animals from NT-Troop in late December, 1977. During the course of the entire study, three adult males were removed and replaced in each group in order to study the effects of social manipulations on the operant performance.

One finding from this study was that we were able to demonstrate response enhancement in 13 out of the 20 animals that completed testing (one animal was dropped because intermittent illness during the fall) in a situation where response patterns were unaffected by temporal control artifacts (Adams, Allen, & Bunnell, 1977). When the operant data were correlated with social variables, it was found that there was a significant correlation between rank and local rate ratio during the two weeks prior to the removal of the alpha male in T-Troop (rho = .70, t = 2.59, df = 7, p = .04). (The local rate ratio is defined as the ratio of rate of responding in the first 12 sec bin following nonreinforcement over the rate of responding in the first 12 sec bin following intervals that were reinforced.) Removal and replacement of the alpha male produced a correlation of +.66 between high rank and high omission ratio and of +.90 between high rank and high local rate ratio. By the end of the study and the completion of the social manipulations, the correlation between rank and local rate ratio was still a respectable +.68. However, in NT-Troop there was no relationship between rank and performance throughout the course of the study. One possible explanation of the discrepancy between the T- and NT-Troop data lies in the differences in the social behavior observed in the two troops. In T-Troop, there was a fair amount of agonistic activity throughout the study and the removal and replacement of different males produced increases in agonistic behavior and some definite changes in rank. In NT-Troop, however, the group was relatively inactive, there was little aggression, and the social manipulations did not produce either a marked increase in aggression or any profound alteration of the rank structure. It may be, then, that the manifestation of social/performance relationships occurs only when active tensions exist within a group and the social structure is under pressure.

To follow up the results of the first study, the animals assigned to I-Troop were continued on the VI 1-min schedule throughout the time that they were withdrawn from their original troops, during the formation of I Troop, and during the current contract year. Social manipulations during this time included the addition of Alabama and Cracker to I-Troop, and the removal (on 9/4/78) and replacement (9/27/78) of Alabama and of Spiro (3/26 - 4/2/79), Yuk (4/9 - 4/17/79) and Gus (4/23 - 5/8/79).

The overall correlation between mean omission ratio for each animal and his rank up through the completion of the formation of the group was +.74 (_t_ = 2.91, df 7, p = .02). If the two youngest animals which were just emerging from subadult status were excluded from the calculation (they seemed to be in the group but not of it at this time) the correlation rose to +.83. The local rate ratio data were similar, but more variable; however, there was a +.94 correlation between local rate ratio and rank during the two weeks following Alabama's introduction into the troop.

In between social manipulations, the correlations between ORs and rank tended to drop off to +.40 to +.50 but would rise again to about +.70 when the manipulations were being made. The data are not quite as clean as we would like because Alabama, the animal that had been alpha since the September manipulation and ranked second after the first of April, failed to complete quite a few test sessions in March and April when the last three manipulations were being conducted. Nevertheless, we are now confident that the rank/OR relationship is real.

Another relationship between operant performance and social behavior has been reported previously (Bunnell and Allen, 1977). Nine T-Troop and 12 NT-Troop males were trained on a differential reinforcement of low rate (DRL) schedule with a limited hold contingency. Social manipulations consisting of removing and replacing key animals took place after the performance had stabilized. On the DRL, a high rate of response bursting was associated with high frequencies of aggressive behaviors in the social situation. This relationship appeared in both adult and subadult males in T-Troop but only for the five males of NT-Troop who were adults when they were tested. A second finding was that good performance on the DRL (a low efficiency ratio) was associated with high rank for both the 5 adults of NT- and the 6 adults of T-Troop that were tested.

Testing on yet another operant task has been completed during the current contract year. The one performance task we have looked at in which high ranking animals have consistently out-performed lower ranking animals has been the DRL schedule. Here the higher ranking animals achieved better efficiency ratios more quickly than lower ranking animals during acquisition. To pursue this further, the T- and NT- males were trained and tested on a changeover ratio schedule. The rationale for this was that the ability to "count" accurately would be a meaningful component of efficient behavior and would perhaps be particularly relevant to a social animal whose well-being depends upon the accuracy of discriminating his position within the group hierarchy. The changeover ratio provides a measure of counting accuracy.

On this schedule the animals are trained to press a lever 12 times after which a changeover to a second response, in this case a door press on the hopper manipulandum, produces a pellet. Responses on the changeover manipulandum which follow an incorrect sequence length are not reinforced, but reset the 12 response requirement on the lever. The animals are allowed to obtain 40 food pellets per day on this schedule.

The data are recorded in sixty response bins (0-59) according to the number of lever presses the animal makes prior to pressing the door of the hopper. (Bin #59 is an overflow counter.) From this, the median number of lever presses the animal makes before it makes a door press is calculated as is the interquartile range and the total number of response sequences initiated by the animal (a sequence is scored anytime the animal makes one or more lever presses before it presses the door). The "0" bin records successive presses on the door without intervening lever presses and is a measure we think may be akin to response bursting under the VI schedule.

F. Projected Research:

(1) Operant testing - laboratory: The master computer program is being rewritten to enable us to use various combinations of multiple schedules. T- and NT-Troop males have been returned to the DRL 18 sec schedule both to replicate the earlier DRL schedule and in anticipation of using a multiple VI DRL schedule this fall. Such a schedule produces positive behavioral contrast in the VI component (Bloomfeld, 1967 and Rachlin, 1973). I-Troop males are on the VI 1-min schedule in anticipation of testing them on a multiple VI EXT schedule which should also produce behavioral contrast. We think that this approach will maximize our chances of producing reliable response bursting that can be associated with the social variables.

(2) Operant testing - social group: We have begun pilot work to test animals on operant schedules while they are in the social group. A testing apparatus, consisting of a box containing a level, pellet dispenser, cue light, microcomputer, and tape recorder has been built and is functional. Programs for various schedules and for recording the data on magnetic tape are plugged in using programmable read-only memory chips with the microprocessor. A number of females that are of particular importance to the social structure of the groups have been shaped on the apparatus by bringing them into the laboratory and giving them experience on CRF schedules. We are now ready for the initial tests of these animals in the group situation. Our experiences with these animals will be used to develop the procedures to be used with the males.

(3) WGTA testing: Six males from each group will be tested on reversal/reversal extinction in anticipation of our plans to monitor cortisol levels. This testing procedes quite slowly and it is likely that only one cycle of reversal and reversal extinction can be accomplished during the year.

(4) Open Field: The 23 experimental animals will be tested in the open field which will contain either a familiar or an unfamiliar animal. They will also be tested to examine responses to a novel object in the field when they are alone and when they are with a "companion". Companions will be selected on the basis of cluster analyses of their social behaviors. Depending on the results of these two experiments, systematic replications of one or both tests may be done.

(5) Data analyses: During the past year we did many factor analyses of performance variables and attempted to relate the factors extracted to the social variables. The objective was to see if we could extract some performance dimensions from the data which could enable us to identify traits which relate to the ease with which a given monkey can establish and maintain high social rank. Because of the large number of performance variables and the relatively small number of animals involved, it was necessary to first factor analyze each behavioral test to extract one or two common dimensions and then factor analyze the factors from several tests to obtain higher order factors which we

hoped to relate to social behavior and organization. The results of applying this procedure have been disappointing to date. The main problem has been a lack of reliability of the factors extracted. We now have considerable additional data, particularly on the WGTA and VI omission and open field and plan to try again with the hope of getting better reliability and on the first order factors and hence a better test of our hypothesis.

(6) Hormone assays: We plan to measure plasma levels of testosterone and cortisol in conjunction with all of the behavioral tests to be conducted during the coming year. We have not attempted this before because of the difficulty of obtaining blood samples from M. fascicularis. The preferred site for drawing blood, the saphenous vein, does not hold up over the course of repeated sampling. Drawing from the femoral would require that we sedate our animals before doing the draws and this we are unwilling to do because of the effects on performance and responses in the social situation. With the help of Dr. Richard Michael and one of his collaborators, Dr. Doris Zumpe, of the Behavioral Psychiatry Laboratory of Emory University, we have been given instruction in a technique for restraining the animals and drawing blood from the tail vein in M. fascicularis with minimum problems. Their data indicate that the animals adapt to restraint quickly and the tail vein allows sampling at intervals that are frequent enough to meet the demands of our behavioral testing schedules. The objective here will be to relate hormone levels to our behavioral construct of "social pressure" which we think is a causal agent in producing the social performance relationships. Cortisol levels are desirable because of this hormone's relationship to responses to stress. Plasma testosterone has been shown to be closely related to social rank and agonistic behaviors by Bernstein and his collaborators (e.g., Bernstein, Gordon, and Rose, 1978). We are now in the process of developing the protocols that are to be used for obtaining the blood samples.

G. Facilities:

In August, 1979, the University of Georgia agreed to pay the costs for recovering the outdoor compounds with 1 in x 1 in chain link fencing and to provide additional bracing and strengthening for the compounds. This work should be completed this coming fall. It will improve the living conditions of the animals and prevent the escapes by infant and juvenile animals that have been of considerable concern to the University and USDA veterinarians. The request for renewal of the contract for the coming year contains a budget item for refurbishing the indoor quarters of the animal groups. This will consist of the installation of a new floor, including a modification of the floor drain, and of covering the walls with stainless steel sheets. Completion of this work will make the indoor quarters much easier to clean and sanitize and eliminate a potential health hazard to the animals.

During the current contract year a hot water system for the power washer used for cleaning cages and the indoor living quarters has been installed. Guillotine doors have been fitted to the outside of the lab building between the swinging doors and the runways to the compounds. This makes it easier for one person to lock the animals in or out of the building for cleanup, removing animals for testing, etc. It also eliminates of drafts in the indoor quarters and will make it much easier to heat these quarters in winter.

Weatherproof boxes containing an operant lever, pellet dispenser, cue light, and a power supply for the microprocessor and tape recorder used for outdoor operant testing have been installed in the T-Troop and NT-Troop compounds.

Conclusions and Recommendations

The work of the laboratory is providing a set of relationships between social behavior and organization on the one hand and individual differences in performance on a variety of laboratory learning and performance tasks on the other. The relationships that have emerged indicate that there are individual differences in performance that are related to the day-by-day and week-by-week changes in, and pressures of, the social group living situation. The development of a construct or model to define and explain these relationships should also lead to methods of protecting individuals from deterioration of performance caused by social factors. The hypothesis that there are individual differences in abilities and traits that are related to the ease with which animals establish and maintain high social rank is also being studied and tested.

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